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Evaluating renewable energy-based rural electrification program in western China: Emerging problems and possible scenarios

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ABSTRACT

Renewable energy technologies offer an economically viable and environmentally suitable scenario towards addressing energy requirements for rural livelihoods. China's Renewable Energy Rural Electrification Program, initiated in 2001, is an effort to employ renewable energy technologies on a large-scale for rural electrification. The Program has been designed with several stages. This paper firstly offers an analysis of the problems encountered during the progress of this rural electrification program, using data obtained from field survey of representative areas in western China where the first stage of the program was implemented. The paper then explores feasible solutions in order to address existing rural energy issues and provide long-term reliable energy service for remote communities. In support of future course of development of renewable energy application for rural energy demands, policy recommendations are provided.

Contents

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1. Introduction

Energy is seen as a linchpin of development, and the welfare impact of rural electrification in terms of improvement in productivity, poverty reduction, livelihood improvement, and environmental sustainability in rural communities are empirically established [1]. At the same time, according to UNDP, currently over 1.6 billion people lack access to electricity and most of them live in poverty in rural areas of developing countries, where connection to the power grid and access to clean fuels are either unavailable or prohibitively expensive [2].

China has embarked on an ambitious plan to electrify all remote communities in phased manner, to improve rural welfare, and ultimately to provide electricity services to all of its citizens. The Chinese government's resolve towards rural electrification was strengthened in its Tenth Five-Year Plan (2001–2005) by the policy to increase domestic production capacity of solar, wind, and geothermal energy systems. The country's Township Program had electrified more than 1000 townships in nine western provinces by the end of 2005. Following this, the next phase of the program is Village Electrification Program, which will provide electricity to remote communities and families at village or settlement levels in western China.

While in the past years there have been significant achievements in this program, problems emerged during the process of program implementation and the flaws in framed energy strategy have affected further progress in energy sustainability of rural communities and their sustainable development. Hence, the second phase of the rural electrification program cannot simply mimic the first phase to arrive at its set goals. Also, there is need to incorporate the lessons of contemporary renewable energy-based electrification programs for the purpose of providing satisfactory energy services to rural communities.

The objective of this paper is to identify the problems of rural electrification in China and discuss possible solutions. In this research, a multidimensional data was collected from representative rural communities and households of Western China to distill lessons and recommend scenarios for the forthcoming second phase of rural electrification Program.

2. Profile of China's rural electrification program

2.1. Overall targets

China's power supply for rural areas has been dramatically expanded during the period of 1960s to 1990s. By the end of 1999, 95% of rural China was electrified through conventional schemes, including grid extension and the exploitation of small hydropower or micro-hydro [3]. Despite these accomplishments, the remaining unelectrified areas represent more than 7 million rural households (3.55% of the whole country) and 30 million people [4,5]. The top provinces (autonomous regions) with highest number of unelectrified households—Tibet, Gansu, Inner Mongolia, Xinjiang, and Qinghai—all located at western or northwestern China. Electrifying these areas by extending grid is unlikely to provide sustaining solution to the energy needs of remote areas of these provinces due not only to its high capital cost of transmission infrastructure but also due to transmission losses and maintenance costs. The cost of grid extension, according to the estimation of China's State Power, is about $5000–$12,750/km [6], which makes this option prohibitive for local people and unmanageable for the government.

Acknowledging the potential of renewable energy options to meet the electric energy needs of rural communities and realizing the economic feasibility, the Chinese government decided to rely largely on renewable energy to meet the electricity demands of rural communities in Western China. The 1996 World Solar Peak Conference in Zimbabwe introduced a worldwide effort for rural electrification called Brightness Program. China immediately assumed a leading role in this action by establishing an elaborate rural electrification program under which around 23 million people were aimed to be electrified by wind and PV technologies by 2010, with the installation capacity of 100 W per capita. The Brightness Program in China includes both domestic and international cooperative projects. In 2002, the scaled up application of renewable energy-based rural electrification action—Township Electrification Program—was initiated. The target areas were primarily communities at 1065 townships across of 12 provinces,[1] which are equivalent to the counties in United States [5].

2.2. Technical approach

Many prominent research papers and reports have enhanced the understanding of promotion of electricity in remote communities from renewable energy in remote communities of Western China [5–8]. The favorable economics of renewable energy application has also been proven. The estimated cost of electricity per kWh from solar–wind hybrid (now on hybrid) system ranges from $0.26 to $0.89, considerably less than the unsubsidized cost of electricity supplied through grid, which is roughly $3.32 per kWh [6]. In terms of the cost of systems, it is estimated that the prices of wind, PV, and hybrid system are 15 RMB/W, 80 RMB/W, and 30 RMB/W[2] respectively [9].

During the process of rural electrification program, the technological approaches were designed according to the distribution of local people. Small and micro-hydropower was given priority where the hydro resource was available. For those areas with clustered households and township infrastructure such as location of village committee, village school, and village health center, renewable energy-based village power systems and mini-grid were installed. While for the decentralized residents, off-grid PV, wind or hybrid household systems were disseminated. This design guaranteed that the local people at different locations can get access to electricity to meet their basic demands. At the same time, the technical design also aimed at developing market-based renewable energy industry.

2.3. Accomplishments

The major achievement of the first phase of renewable energy-based electrification program is that it electrified all of the country's townships. More than 2000 townships and 8 million people actually benefited from the Program so far. The data of Township Program 2004 [10] point out that around 688 PV or PV/wind hybrid mini-grid systems with a total capacity of 20 MW_P has been installed. Around 377 small hydropower mini-grid systems were in service, with a total capacity of 264 MW. Meantime, more than 1.78 million renewable energy household systems were disseminated. The total investment of Township Program reached 4.7 billion RMB [10].

What distinguishes China's program from other countries and its own previous efforts is scale. This could be proven by the fact that the number of people without electricity fell from 2 billion to 1.6 billion worldwide between 1990 and 2005. However, excluding China, the number of people without electricity has grown [11]. The following Fig. 1 illustrates the rapid decrease of China's unelectrified population as well as electrification rate. By the end of 2005, China's electrification rates of county, township, village

[1] Most of them are western provinces: Xinjiang, Qinghai, Gansu, Inner Mongolia, Shaanxi, Sichuan, Yunnan, and Tibet.

[2] Current exchange rate 1 USD equals approximately 6.80 RMB.

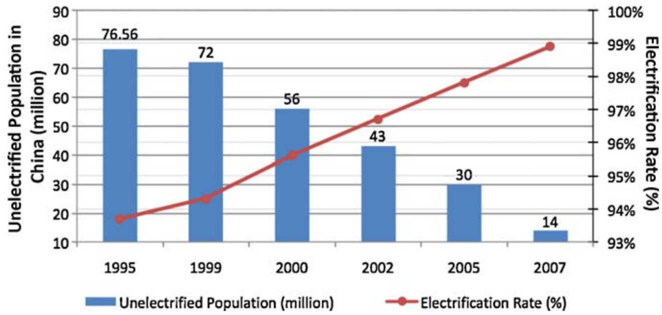

Fig. 1. China rural electrification rate (population) and unelectrified population (1995–2007).Source: [7,9,11–13,15].

and household are 100%, 99.9%, 99.8%, and 99.4% respectively [12]. In 2006, 12 provinces of China were added to the inventory of provinces which have achieved electrification for all households. China's rural electrification is the largest contribution to the decrease of global unelectrified population.

2.4. Financing arrangement for rural electrification

One of the integral components of the first phase of the rural electrification program was to establish primary financing scheme, marketing mechanism, and training activities, which holds very critical significance for the success of the overall program. Currently adopted most common practice of financing mechanism involves sourcing funds from multiple channels. The governments at different levels such as central or provincial, international donors, and local micro-enterprises, among others, play a significant role in the contribution to the project funding of such kind. The local communities, considering their low income level, share a small part in the system investment. More than 90% of the funding has come from government sources, international donors, and district and county contributions [7]. Some systems, in Tibet for example, are completely funded by central or provincial government. But, as the direct beneficiaries of a dedicated electricity supply, remote communities are normally willing to make a further contribution towards expansion of such systems to meet their electricity needs [7].

Many private sectors entities compete for government-supported projects and they have played an active role in the entire project cycle, such as project development, system design, installation, and management. Although their participation at various stages of the project is presently limited by financial performance, in the future the encouragement to involve them could prove crucial to the possibility of realizing commercial viability of rural electrification program to be able to best serve rural community's energy demand.

3. Challenges of rural electrification program in western China

The basic electricity demands of all townships/administrative villages have been met through China's Rural Grid Rebuilding Project[3] and the first phase of Rural Electrification Program. It is no doubt that the remaining communities and settlements, which are the targets to be covered in the next phase of China's Rural Electrification Program, are much more scattered and farther from the main electric grid. Therefore, off-grid renewable energy options will continue to be the necessary scenario in the forthcoming Program.

The work of the first phase of rural electrification program paid extensive attention to the initiative and installation of a broad range of PV, wind, and various hybrid systems. Also the Chinese government entrusted research institutes or companies to collect necessary data for the initiative of the next phase. For example, the comprehensive investigation of unelectrified villages in Tibet has been achieved by 2004. However, surveys of the long-term performance of the Program are incomplete. The quality of components and complete systems of renewable energy technologies remains an issue in China [13]. For the purpose of improving the quality of rural electricity service and implementing the second phase of Rural Electrification Program successfully, a survey was conducted in our research to obtain a representative profile of renewable energy system and identify its typical problems in this research.

3.1. Description of the survey

In collaboration with our Chinese partner, Center for Renewable Energy Electrification Consultant and Training (CREECT) of the Institute of Electrical Engineering, the Chinese Academy of Sciences, the survey was conducted at representative townships and households in provinces of western China. The survey also formed a part of a research project of the World Bank/GEF China Renewable Energy Development Program.

The primary objective of the survey is to identify problems encountered during the process of rural electrification by renewable energy options, such as system operation, maintenance, management, quality control, and tariff mechanism. It was conducted on three different categories that included the following: (1) village power system and household system, (2) users of renewable energy power system, and (3) power companies and local utility service. The survey offers valuable lessons from the experience of the first phase of Rural Electrification Program, which can be very instrumental for future project implementation towards improving system performance and establishing long-term reliability.

The final target of Rural Electrification Program is not merely the satisfaction of daily basic energy demands, but also poverty reduction and economic development of rural communities and ultimate improvement of the welfare of people in rural areas. System design should carry requisite capacity to maneuver according to future load expansion and changing users' requirements. The survey targeted on users is aimed to collect data pertaining to following aspects: (1) the electricity demands of local communities at current level, (2) the users' attitude towards off-grid PV, wind, or hybrid systems, (3) the local users' future demands, and (4) the users' affordability and willingness to pay. The questionnaire was designed to get such information to estimate the remote communities' electricity demands in the future and the consumption profile of power in a certain period of time.

The survey on local utility companies was conducted to get information about: (1) population of local communities, their level of economical development and extent of energy consumption, (2) price of electricity and status of tariff collection, and (3) the cost estimation and comparison between renewable energy program and Rural Grid Rebuilding Project.

3.2. Lessons learned through the survey

3.2.1. Attention to the long-term and reliable electricity service is insufficient

The ultimate aim of rural electrification program is to provide a long-term and reliable electricity service to targeted rural

[3] Rural Grid Rebuilding Project includes rural grid extension, infrastructure construction, equipment update and other electrification options. Its objective is to serve reliable electricity to more rural communities and achieve the same electricity price for rural and urban areas.

population. The infrastructure building forms essential part of whole project which actually does not require long time in case of renewable energy options. The electricity service, however, needs long-term commitment from the side of service provider. Our survey of typical village power project found that the target of a large number of off-grid PV, wind power, and hybrid projects in remote areas was limited to system installation. The lack of attention to service commitment, plus uncertain ownership (discussed in later part), usually led to a series of problems for Rural Electrification Program such as weak system reliability and changed attitude towards renewable energy options.

3.2.2. Electricity generation capacity and quality are required to be standardized

To satisfy the basic electricity demands forms the core of the project design. However, to date, this is remaining a desired qualitative requirement only where the lack of detailed requirements of generation capacity and quality standard of electricity had hardly any scope of system optimization. The designed scenario of rural energy program usually neglected the potential of optimizing the application of various energy sources available in local context. Instead, a fixed configuration was used for large areas without appropriate adjustment according with local situation.

3.2.3. System quality control is still weak

System quality control is a process employed to ensure a certain level of quality in a product or service to meet specific requirements and fiscally sound. Quality control is one of the core issues of renewable energy system to guarantee a reliable energy service. It operates at each step of the project, such as site assessment, technical scenario, system components, engineering bidding, installation, commissioning check, operation and maintenance (O&M), and management.

Some research believed that the technologies for rural electrification such as PV and wind are matured and products should be commercially supplied with adequate warranties. And the failure of renewable energy projects was mainly attributed to improper use or abuse of equipments [7]. However, our survey illustrates that the weak quality control at the manufacturing level of components integrated to the system operation level accounts largely for system problems. Also it was observed that the program lacked mechanism of comprehensive quality management, especially commissioning check and supervision.

Table 1 indicates the incidents of system failure and blackout surveyed for 66 village power systems in Xinjiang. Among all of the power blackouts, 90.8% was caused by malfunctioning of system components rather than caused by improper use. Another survey conducted in 2004 shows that the qualification rates of 10W_p and 20W_p were 88.9% and 62.5% respectively, indicating strongly the need for further qualitative improvement [14]. It is obvious that the enhancement of system quality control plays a key role in improving system lifetime and reliability, which in turn, affects many other aspects of rural electrification program.

Table 1
Profile of power blackout and system shutdown of 66 village power systems operated in Xinjiang.

Power failure cause	Times	Percentage
Power line malfunction	36	36.7%
Equipment malfunction	53	54.1%
Operation failure and others	9	9.2%
Total	98	100%

Source: [14].

3.2.4. Operation and maintenance of village power system requires enhancement

Besides quality control, proper O&M is vital to the lifetime and reliability of village power system. The bidding process of Township Program usually identified the contracted system construction enterprises, while neglecting the O&M after the system installation. The proper operation of the systems and reliable provision of services, therefore, is hard to be guaranteed where the O&M is given minimal importance.

Although some village systems in Xinjiang are operated through contracted operation, our survey indicates that most of them lack a complete and clear terms about rights and responsibilities of both system owner and contractor. In the following stage of rural electrification Program, detailed contract with clear O&M principle, service level and requirement, and tariff regime should be framed for arriving at the desired goal. Successful O&M process is also closely connected with proper establishment of ownership and management of village power system, which is discussed below.

3.2.5. Ownership and management responsibility of renewable energy power system are unclear

A clear ownership is equally essential for effective functioning of renewable energy system as the management and O&M. The "confused ownership" [7] arrangement has posed great challenges to operating practices and maintaining the service of many existing systems we surveyed.

System ownership is conventionally determined by the sources of investment for the installation of a system [7]. For small-scale household system, the users are usually believed as the owners if they directly purchased it. However, most of the household systems in China have availed a large extent of government and international financing. For example, the survey noticed that for a PV household system used in "Silkway Brightness Program" of Xinjiang,[4] out of the total price of 2650 RMB, 700 RMB (26.4%) came from users directly while the remaining 73.6% was from donors. Another such an example is China's Renewable Energy Development Program where World Bank's subsidy shares 15–20% of the total system cost (\$1.5–2/W_p) [14]. There is no stipulation of the ownership transfer of systems financed through governmental sources and international donors.

Nor the ownership of village power system is clear. The investment towards village power system is drawn mainly from government and international organization due to its large capacity and high cost. There is no documentation to recognize it as national assets and no evidence of being managed by national asset committee. Further, the ownership rights have not been sufficiently transferred to local parties, such as the rural communities, to allow them to take over the complete responsibilities of the systems installed [7].

Most of the renewable energy electrification projects implemented in China were never scrutinized by any official and specified commissioning check, which in turn had various problems in the course of the O&M and management of the Program. As well, there was no supervision mechanism. Even some projects that were put under sampling and test, such processes only focused on quality of manufactured components, while ignoring the system operation and service.

The management guidelines of Township Program failed to comprehensively consider the whole process that involved

[4] The Sino-Holland Silkway Brightness Program disseminated 78,000 PV household systems for remote families (around 300,000 people) in Xinjiang Uygur Autonomous Region. 60% of the total investment was come from the Netherlands government. It is one of the important components of China's Brightness Program. The whole project had been finished by November of 2007.

program planning, feasibility analysis, construction, and O&M. Detailed and practical management procedure and examining index, directed against different stages of the electrification project, are still at formative stages.

3.2.6. The tariff collection is haphazard

The ambiguity surrounding the management responsibility directly resulted in irregular stipulation of tariff collection. The village power systems are temporarily managed by village government or committee without certain set criteria, and often they determine the tariff level and revenue distribution by themselves that many a times led to chaotic situations.

Partially the absence of effective O&M and management mechanism accounts for the wide gap between tariff and costs in some areas. Our survey on the PV stations of KfW Program[5] indicates that even though the users were charged 2 RMB per kWh, which represented a tariff with subsidy and higher than the usual electricity price, the collected tariff could not generate enough revenue for the salaries of operators, let alone system O&M and parts replacement.

In our survey on the subsidized tariff mechanism, we found that such a subsidy was only granted to the stand-alone systems installed after 2006, while the installation before that did not avail the subsidy. Lack of subsidy has led to a series of problems like the loss of operator and failure to update the system components. The village power systems installed before 2006 are therefore facing the situation of possible malfunction. On the other hand, it is a kind of policy limitation that the household system cannot share this subsidy.

3.3. Potential of electricity service increment

Our energy level survey on Township Program in Xinjiang and Qinghai provides data regarding current rural energy consumption patterns of households and village power systems and their growth potential. Table 2 lists the percentage of rural households and communities that own various electrical appliances powered by different systems in Qinghai Province—household PV system of KfW Program and village power system of Township Program. The typical household electricity consumption served by PV household system is shown in Table 3, taking into account their family financial status. It shows that the electricity consumption of users of household system is still at the very basic level.

Under the rural electrification program, it was designed to provide adequate level of electricity to fulfill the basic electricity demands of individual households as well as community-based consumption. These demands are limited to lighting, running TV, and rural public facilities such as village schools and clinics. However, Table 2 indicates that with the improvement of economic conditions, new electrical appliances having higher energy appetite are appearing in remote household, such as refrigerator, rice cooker, washer, and appliances for family-scale production. Addition of such appliances in the overall electric appliance portfolio of rural areas dramatically increases rural household and public loads, expressing higher requirements for both service time and quality of electricity in the near future.

3.4. Users' willingness to pay and attitude towards renewable energy options

All surveyed households signaled that there is steady growth in electricity consumption. Most of the families we interviewed expressed their satisfaction incorporating electricity services in their daily lives. They showed, in turn, their preference for off-grid renewable energy power systems to meet their future energy demands. In Xinjiang and Qinghai, almost all the families which had average income level or above expressed their willingness to pay for renewable energy systems and electricity services.

In the survey, local residents preferred to spend on renewable energy system rather than conventional fossil fueled generators. This finding may be attributed to two factors. First, because of their remote location coupled with increasing price of fossil fuels, the delivered fuels to rural communities are extraordinarily expensive. Furthermore, the uncertain means of fossil fuel transportation in rural areas makes such conventional energy systems less reliable than renewable energy systems. Second, with the governmental and international support, the prices of renewable energy system that provide electricity services in rural areas are found reasonable. The subsidized tariff makes the renewable energy options affordable for local communities.

The survey results, from the users' perspective, underscore two issues which are significant for rural electrification program design and implementation. One is the warranty of system reliability and quality of electricity service. Such a warranty can speed penetration of off-grid renewable energy systems which might otherwise face resistance as local people continue to expect conventional way

Table 2
Ownership rate of electrical appliances under KfW Program and Township Program in Qinghai Province, China.

Category	Electrical appliances	KfW Program	Township Program
Basic power load for daily life	Fluorescent lights	3/household	2.5/household
	B&W TV	0.2%	
	Color TV	19.9%	72.6%
	Satellite receiver	19.9%	56.0%
	DVD player	12.5%	54.1%
	Cassette radio recorder	33.2%	
Large power load for life	Refrigerator	1.2%	42.5%
	Washing machine	3.6%	22.0%
	Rice cooker/electrical pot	0.2%	
Productive load	Feed grinder	0.2%	
	Woodworker	0.2%	
	Grain processing machine		0.3%
Community public load	Water pump	0.2%	
	TV repeater		
	Mobile communication		
	Computer	0.6%	8.7%
Total surveyed stations		10	7
Total surveyed households		497	924

Table 3
Daily electricity consumption of rural households powered by KfW Program.

Program location	Household economic status	Surveyed household number	Population (persons)	Average person per household	Household daily electricity consumption (kWh)
Yunnan	Above ave.	11	48	4.4	0.386
	Average	36	160	4.4	0.327
	Below ave.	23	94	4.1	0.138
Xinjiang	Above ave.	23	90	3.91	0.629
	Average	30	122	4.07	0.552
	Below ave.	N/A			N/A

of electrification. The second issue highlights necessity of a proper mechanism to decrease generation costs, and an effective tariff regime of renewable energy power generation designed to generate enough revenue for the system to break even or operate with low profit, while maintaining the price of electricity is affordable to rural people.

4. Policy strategy for addressing issues of renewable energy development for rural electrification

Our study illustrates that during the first phase of rural electrification Program, barriers—ranging from low quality to a vague ownership and ambiguous tariff regime—can prevent off-grid renewable energy applications from reaching its full potential that was desired by Rural Electrification Program. An important lesson from our research is that the removal of such identified barriers is essential for successful implementation of further renewable energy option. Below we offer a framework for addressing these issues that can be deduced from the previous case but which we believe is broadly applicable to rural electrification initiatives of other developing countries with similar situations.

4.1. Looking for multi-channel for system funding

A multi-channelled way to raise funds for renewable energy power system is needed to promote system building as well as O&M, especially in remote rural communities. The financial support for power construction is usually invested by both the central and local governments. A possible option for the near future is that the central government shares 50% or more[6] of the total construction investment, through government budget, or national debt, or from international borrowings individually or combined as the case may be, while the governments at provincial and county levels share remaining financial burden. In particular, subsidized budget for O&M and management of power systems, as a fundamental practice to guarantee the system sustainability, should be integrated into local government's planning processes.

4.2. Creating quality control mechanism

A comprehensive quality control mechanism is essential, especially when one considers the erratic and low quality of power service in remote areas. Toward this end, facilities with potential of providing high quality energy services should be selected during the process of system building, and the technical standards of power services could be carefully established for effective realization of reliable and quality guaranteed electricity services to rural communities. Further, some sort of certification maybe encouraged to be issued to those manufactures and installers who satisfy certain standard.

To meet the requirement of quality control at each step of Rural Electrification Program, right from project initiative to installation and to service management, an independent and impartial third-party organization can achieve assessment, check, and supervision of system quality control. Such an organization could be determined and supervised by government or concerned supervision committee, maybe made of stakeholders, for its payable service.

4.3. Clarifying ownership and management responsibilities

Sustainable service of renewable energy power systems often depends upon clear ownership and management arrangements. Therefore, there exists a need to change such essential aspects of current Rural Electrification Program, so that rural power system could be operated properly and rural users can enjoy reliable services. One important aspect to arrive at successful project scenario would involve participation of local parties to take over the ownership of village power system clearly and in sufficient terms. This could possibly provide sustained solution to current practices beleaguered by ownership and management ambiguities.

Currently, rural electrification program are financed through multiple funding channels and sources. Some of the financiers are alleged to lack direct interest in system performance. It is suggested that the key to solve this problem lies in a clear separation of ownership and management responsibilities [7]. However, most of rural electrification system is directly managed by local government or a village committee with undefined ownership. The disadvantages of such non-commercial pattern of O&M are obviously reflected in terms of poor technical and economic support, insufficient revenues and unreasonable distribution.

Commercialized management pattern can help to ground sustainable operation of village power system in broader market environment. Possible scenarios of commercialized model could be contracted or leased for O&M. These options centered on the idea of separation of ownership and management where operators would have incentives for optimized system operation to make profits. Compared with contracted model, leased arrangement is closer to true commercialized process. Individuals and legal entities who lease the system would have the full right to operate system, provide service, and create profits in their own way. Legal entities could be local utility companies or other enterprises selected through entrustment or bidding. Meantime, the owner of the system can get payback from the investment and therefore adopt set-asides for future development.

[5] KfW Program is Sino-Germany ‘‘PV Village Power System’’ project cooperated between Department of Financing of China and German government-owned development bank—KfW, initiated in 2001. The program objective is to support the installation of up to 210 village power systems for around 10,000 households. As well, it is an important component of international projects in western China's rural electrification.

[6] The shares of investment change with projects and locations. For example, the funds for Township Program in Tibet are all from national appropriation. In Qinghai central government shares 80% of the investment.

4.4. Building a sound tariff collection regime

One of the primary obligations of management is to collect tariff which forms essential input for economic viability of renewable energy power systems. The previously followed complex tariff collection is attributed to unspecific management arrangement. To set a sound tariff collection regime to operate effectively with the commercialization of system operations, two questions have to be addressed: firstly, how to determine appropriate tariff level, and secondly, how to bridge the gap between the tariff collection and generation cost.

Currently, the subsidized tariff is now widely charged to the users, and the governmental funds are generally used for system maintenance. However, due to the insufficiency of funding and demand increment, this regime cannot be sustained when the subsidies are removed and the price of electricity subsequently rises. Instead, profitable or break even tariff regime should be designed for commercialized management of power systems. Under the framework of such a regime, the management should take due consideration of both the costs related to system maintenance and paying capacity of local users. As the future demands grow, pricing level based on different appliances may be suggested.

The application of cross-subsidy as a necessary means to fill the gap between the revenues and costs associated with power systems deserves special attention, which has been proved successful by the experience of developed countries and has been incorporated in China's *Renewable Energy Law*. There is a great effort in China to create a uniform pricing policy for electricity services in urban and rural areas. Cross-subsidy regime provides funds by sharing the costs of system O&M, management, and even the initial costs of decentralized renewable energy system by the entire grid. Cross-subsidy is an incentive mechanism transfers the partial cost renewable energy options to the whole power grid. Such a transfer of tariff difference, along with preferential loans and grants for renewable energy options, could offer the electricity services to the decentralized users at comparable or the same price as their counterparts covered by grid power. In turn, the price competitiveness of off-grid power can ultimately lead to renewable energy's quicker penetration in remote areas if application procedures and cross-subsidy standards are well placed.

4.5. Expanding system design for future load growth

Finally, the potential load growth in remote communities is substantial. To meet this demand, a projection of electricity requirement for the next decade is needed, which can be estimated reasonably by extrapolating the annual growth rate of past 3 to 5 years observed after the installation of renewable energy systems. Generally, the design of system according to the load anticipated for future 5 years is helpful. In addition, any scaleable system design, mainly based on modular electrical devices would be useful for load growth associated with power system installation.

5. Conclusion

Some of the problems that were encountered during the first phase of rural electrification Program pose new challenges for future progress of this program. To provide a long-term and reliable electricity service from off-grid renewable energy system formed ultimate goal that most rural electrification programs strive for. Realization of such a goal would entail streamlining of many aspects of the rural electrification program, such as system quality control, O&M, ownership, management, and tariff regime. Adoption of effective policies—the establishment of multi-channel financial sources to support rural electrification program development, the creation of quality control mechanism to guarantee long-term system reliability, the clarification of ownership and management to spur commercial operation of systems, the implementation of sound tariff regime to improve economic viability, and the enhancement of system capacity to meet future demands—will address the challenges effectively, and in parallel, stimulate the success implementation of next phase of China's Rural Electrification Program.

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